WELCOME TO ASTROGATOR!

Mission Control Sequence

- INIT 28 deg Inclined Orbit
- Propagate 2 Hours
- Begin Hohmann
  - △ DV1
  - ↵
- Propagate to Apogee
- Finish Hohmann
- Propagate to Ascending Node
- Simple Plane Change
- Propagate 36 Hours

Astrogator Browser

- Central Bodies
- Points
- Vectors
  - Central Body Vectors
  - Vehicle Local
- Axes
- Coordinate Systems
- Calculation Objects
- Engine Models
- Propagators
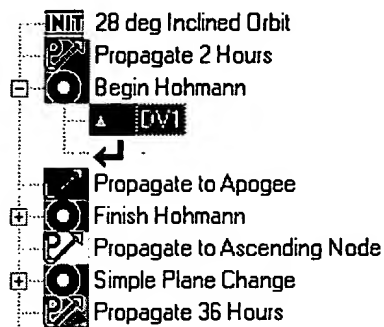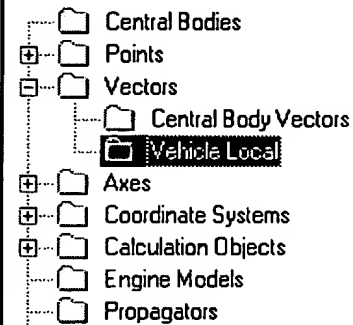
Exercises

Equations & Constants
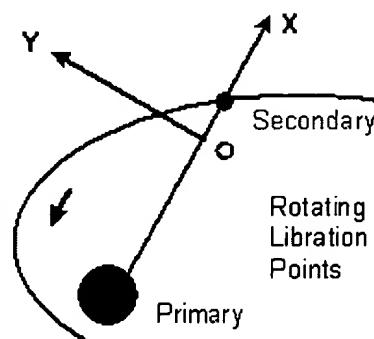

Secondary

Rotating
Libration
Points

Primary
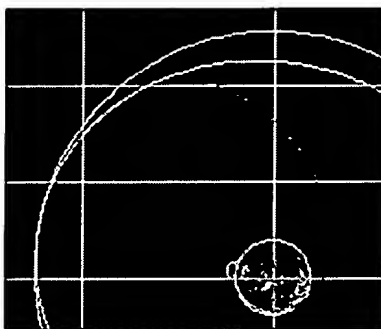
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Maneuvers

Astrogator provides two basic types of maneuvers -- impulsive and finite -- for use in constructing your space mission scenario. Both types of segments are available for building up a Mission Control Sequence in the Orbit tab of the Satellite Basic Properties window. In addition, both of these maneuver types can be used as a basis for creating new segments with the Astrogator Component Browser.

Impulsive Maneuver Segment

The Impulsive Maneuver segment models a maneuver as if it takes place instantaneously and without any change in the position of the spacecraft. This is the classic 'Delta-V' (Δ V). The final state vector is calculated by applying the specified Δ V vector to the initial velocity vector (respecting the coordinate system, of course). The Impulsive Maneuver window lets you specify the following parameters:

Parameter	Description
Thrust Axes	Click the ellipsis (...) button and select the thrust axes to be used in modeling this maneuver. These constitute the coordinate system of the Δ V vector.
Vector Type	Select between: • Cartesian -- enter values for the components displayed for the selected thrust axes (usually X, Y and Z). • Spherical -- enter values for the azimuth, elevation and magnitude of the velocity vector.
Engine Model	Click the ellipsis (...) button and select the engine model to be used in modeling this maneuver. Select whether to have the mass of the spacecraft decremented on the basis of fuel usage. The Decrement option has no effect on the Δ V itself. If selected, however, the mass of the spacecraft will be decremented by an approximated Δ M, using the rocket equation.: $$\Delta V = V_e ln(m_0/m_f)$$ where V_e = exhaust velocity, m_0 = initial mass and m_f = final mass, and thrust and I_{sp} are held constant to their values at the beginning

of the burn. See the <u>technical notes</u> for the derivation of the equation relating change in mass to ΔV.

Finite Maneuver Segment

The Finite Maneuver segment takes into account changes that occur throughout the duration of the maneuver by numerically integrating the effect of the acceleration from the engine. The Finite Maneuver window presents the following options:

Parameter	Description
Attitude Control	Select among: • Along Velocity Vector -- Attitude is such that the total thrust vector is aligned with the spacecraft's inertial velocity vector. • Anti-Velocity Vector -- Attitude is such that the total thrust vector is opposite to the spacecraft's inertial velocity vector. • Thrust Vector -- The total thrust vector can be specified in cartesian or spherical form in the thrust axes (see below).
Thrust Axes	Click the ellipsis (...) button and select the <u>thrust axes</u> to be used in modeling this maneuver. These constitute the coordinate system for the maneuver.
Attitude Update	Select between: • Inertial at ignition -- Specified by Attitude Control at ignition and remains the same throughout the maneuver. This fixes the thrust direction in the inertial direction calculated at the beginning of the burn and is used for inertially fixed spacecraft. • Update during burn -- Updated throughout the maneuver so as to maintain the required thrust direction. This forces the thrust vector to the specified direction at every instant throughout the burn. The thrust vector therefore rotates with the specified coordinate system (in case the Thrust Vector option is chosen) or tracks with the spacecraft's inertial velocity vector (if the Along Velocity or Anti-Velocity Vector option is chosen).
Vector Type	Select between: • Cartesian -- enter values for the components displayed for the selected thrust axes (usually X, Y and Z). • Spherical -- enter values for the azimuth, elevation and magnitude of the velocity vector.

	This field is active only if Thrust Vector is selected as the Attitude Control option (see above).
Stopping Conditions	Click the ellipsis (...) button to display a Propagate window, insert and/or remove one or more stopping conditions in that window and dismiss it. The Stopping Conditions frame in the Finite Maneuver window will be updated to reflect the selections made in the Propagate window. To set a trip value for a stopping condition, highlight it and enter the desired value in the Selected Condition field. Typically, the condition selected to stop the maneuver will be Duration, Epoch or Delta-V. The default Maximum Propagation Time is 7 hours.
Engine Model	Click the ellipsis (...) button and select the engine model to be used in modeling this maneuver.
Pressure Mode	Select between: • Pressure-Regulated -- Constant pressure is maintained in the rocket engine through some pressurization mechanism as the propellant mass decreases. • Blow-Down -- Pressure decreases as propellant is consumed and the volume occupied by the gasses consequently increases. This is based on the ideal gas law.
Thrust Efficiency	Enter the thrust efficiency value. Any number above zero is valid, with typical values around 0.98 to 1.02. A value of 1.0 means 'perfect' or 'nominal' behavior. A value of 0.98 would be termed a '2% cold' burn, while a value of 1.02 would be a '2% hot' burn. □ A value greater than 1.0 means the engine has performed better than expected. The Space Shuttle does this frequently, as reflected in commands such as "go for 104 percent throttle up."
Thrust efficiency affects...	Indicate whether the thrust efficiency value ... • affects acceleration calculations only • affects acceleration and mass calculations

Orbit Propagation

Propagation of an orbit is handled by the Propagate segment, the central feature of which is a mechanism for defining one or more conditions for stopping the propagation or initiating a follow-up sequence. The Propagate window offers the following options:

Option	Description
Propagator	Click the ellipsis (...) button and select a propagator from the list that appears.
Stopping Conditions	To add a stopping condition, click the Insert... button and select one from the list that appears. To delete a stopping condition, highlight it and click the Remove button. When a stopping condition is satisfied, the propagation stops or, if a follow-up sequence has been specified for this stopping condition (see below), that sequence is executed. When more than one stopping condition is selected, propagation stops (or control passes to the follow-up sequence) as soon as one of them is satisfied. ◻ If the propagation seems to be stopping prematurely, check whether it is due to the Maximum Propagation Time setting. Also, you can run a Summary Report for the Propagate segment to find out why it has stopped.
Trip	Use this field to set the desired value for the highlighted stopping condition, i.e. the value to be achieved in order for the condition to be deemed satisfied.
Tolerance	Use this field to set the desired tolerance within which the trip value must be satisfied for the highlighted stopping condition.
Sequence	Click the ellipsis (...) to the right of this field to select an action or sequence of actions to trigger if the highlighted stopping condition is satisfied. Further sequence options can be added using the Control Sequence Browser. The Stop sequence will stop propagation in this segment and allow the next segment to run. If an alternate sequence is selected, it will be run and, when finished, the current Propagate segment will continue to run until a Stop is triggered.
Central Body/ Coordinate System	Use this field, if appropriate, to select a central body or a coordinate system for the highlighted stopping condition. For example Periapsis stops the propagation on perigee if the Earth is the central body and on periselene if the Moon is.
User Calculation	Use this field, if appropriate, to select a User Calculation Object for the highlighted stopping condition. For user-defined stopping

Object	conditions, use this field to specify what kind of value you want to stop on.
Criterion	This field is activated when certain stopping conditions are highlighted. Select among: ● Cross Increasing -- the stopping condition is satisfied when the parameter reaches a value equal to the trip value while increasing. ● Cross Decreasing -- the stopping condition is satisfied when the parameter reaches a value equal to the trip value while decreasing. ● Cross Either -- the stopping condition is satisfied when either of the above situations occurs.
Repeat Count	This field is active for most stopping conditions (those capable of being satisfied more than once in the course of an orbit propagation). Specify the number of times the condition must be satisfied before the propagation ends or moves on to the designated follow-up sequence.
Constraints	Click the ellipsis (...) button and, in the selection window that appears, select a constraint for the highlighted stopping condition. This is a further condition that must be met in order for the stopping condition to be deemed satisfied.
User Comment	Enter a text string to remind you later of the reasons for the various settings you have made for this propagate segment.
Advanced...	Click this button to set one or both of the following options: ● Minimum Propagation Time -- No stopping conditions are checked until the specified amount of time has elapsed. ● Maximum Propagation Time (Optional) -- Setting a maximum propagation time prevents the propagation from running indefinitely if none of the stopping conditions can be satisfied.

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Targeting

The Target Sequence segment gives Astrogator the powerful capability of modeling complex space flight situations quickly and accurately by defining maneuvers and propagations in terms of the goals they are intended to achieve. The method used is a differential corrector with a singular value decomposition algorithm.

Setting up the Targeter

The Target Sequence segment has associated with it one or more nested MCS segments, such as maneuvers and propagate segments, for which control variables and constraints are defined. Setting up the targeter involves making certain selections within these nested segments and in the Target Sequence segment itself. Any segment can be nested in a target sequence, and it is not uncommon to have the entire MCS nested in a target sequence. You can also insert a target sequence within another target sequence.

- Because the targeter references the nested segments by name, each segment within a target sequence should have a unique name.

Selecting Control Variables and Constraint Elements

Any element of a nested MCS segment that is available for selection as a control variable will be identified by a target icon appearing adjacent to it. To select a given element as a control variable, simply click the associated icon. Your selection will be confirmed by the appearance of a check mark over the target icon. If you change your mind click the icon again; the check mark will disappear. You can select control variables in more than one nested segment and, in each, you can select as many control variables as you wish.

Targeter constraints are defined in terms of Astrogator's extensive repertoire of Calculation Objects (to which you can add). To set constraints for a given nested MCS segment, click the Results... button appearing in the upper right corner of that segment's window. This will bring up the User-Selected Results window for that segment. Here, Calculation Objects are selected for constraint definition, but their desired values are specified in the Targeter Controls and Constraints window, described below.

Configuring the Target Sequence

The Target Sequence window presents the following options for configuration:

Option	Description
Action	Select among: ● Run Corrected Control Values -- Run the Target Sequence using control values resulting from corrections made during previous runs. ● Run Nominal Control Values -- Run the Target Sequence using the initial, uncorrected values for the control variables. ● Run Targeter (Calculate New Control Values) -- Run the Target Sequence, calculating new values for the control variables in an attempt to satisfy the selected constraint.
When Targeter Converges	Select the action to be carried out if and when targeting has converged: ● Run to Return and continue -- Run to the first Return segment in the sequence, then pass control to the next segment *after* this target sequence. Usually the only Return is at the end of the target sequence. ● Run to Return and stop -- Run the target sequence to the first Return segment, and then stop running the MCS altogether. ● Stop -- Stop the MCS as soon as the target sequence has converged.
Edit Controls and Constraints...	Click this button to bring up the <u>Targeter Controls and Constraints</u> window.
Add/Modify Profile List...	Click this button to bring up the <u>Targeter Profiles</u> window.
Clear all Corrections	Restore control variables to original, pre-correction values.
Apply all Corrections	Reset nominal values of control variables to take corrections into account, and set the corrections to zero.
Maximum Iterations	The number of complete iterations of the Target Sequence to try before stopping.
	Select this option to have a popup window appear during targeting to report the status of the targeting effort in terms of proximity to the desired value for each constraint.

Display Popup	▫ Instead of closing the popup to get it out of the way, you may wish merely to reposition it. When you run the targeter again, it will use the same window.
Convergence Criteria	Select between: • Constraints within tolerance • Constraints or last variable change within tolerance (last variable change is the last increment to the control variables)
Advanced Options...	Click this button to bring up the Targeter Advanced Options window.
Log File	Select this option to have the targeter generate a log file. Accept the default filename or click the ellipsis (...) button to select a new path and filename for the log file. To review the most recently generated log file, click the View... button.
Converged on last run	One of two values will be displayed in this read-only field after running the targeter: • True -- targeting converged for all selected constraints. • False -- targeting failed to converge for at least one selected constraint.

Editing Controls and Constraints

This window displays information about the control variables and constraint elements you have selected for the current Targeter Profile and allows you to enter information pertinent to each.

Editing Control Variables

Each control variable you have selected is listed here, along with the following information:

• Used (?) -- If an X appears in this column, the variable is being used.
• Name -- The name of the element selected as a control variable.
• New Value -- The value of the control variable after the the last targeter run.
• Last Update -- The amount by which the value of the control variable changed during the last targeter run.
• Segment -- The MCS segment to which the element selected as a control variable belongs.

The following fields, some of which are editable, appear below the Control Variables

list:

Field	Description
Use	Select this option if the control variable is to be used in this run of the targeter.
Nominal	The nominal value of the element selected as a control variable. Read-only.
Correction	The amount by which the nominal value of the control variable should be corrected to satisfy the selected constraints. Enter a first guess here if you like.
New Value	The value of the control variable after the last targeter run. Read-only.
Last Update	The amount by which the value of the control variable changed during the last targeter run. Read-only.
Tolerance	The smallest update to the control variable to be made before the targeter stops. Read-only if the convergence criterion is set to Constraints Within Tolerance.
Perturbation	Enter the value to be used in calculating numerical derivatives.
Maximum Step	Enter the maximum increment to make to the value of the control variable in any one step.
Scale	Enter a specified scale value if this option has been selected in the <u>Targeter Advanced Options</u> window.

Editing Constraints

Each constraint element you have selected is listed, along with the following information:

- Used (?) -- If an X appears in this column, the element is being used.
- Name -- The name of the Calculation Object used as a constraint element.
- Desired -- The desired value for this constraint element.
- Achieved -- The value achieved for this constraint element during the last targeter run.
- Segment -- The MCS segment for which this constraint has been selected.

The following fields, some of which are editable, appear below the Constraints list:

Field	Description
Use	Select this option if the constraint element is to be used in this run of the targeter.
Achieved Value	The value achieved for this constraint element in the last targeter run. Read-only.
Desired Value	Enter the desired value for this constraint element.
Difference	The difference between the achieved and desired value for this constraint element. Read-only.
Convergence Tolerance	Specify how close the targeter should come to the desired value before stopping.
Scale and Weight	Enter a specified scale value and weight if this option has been selected in the Targeter Advanced Options window.

Targeter Profiles

This window provides a means of defining and storing a number of alternative targeting profiles for use in your space mission scenario. A list of all profiles that have been defined for the current Target Sequence is displayed at the top of this window and is duplicated in the main Target Sequence window.

To create a new targeter profile, highlight an existing one and click the Duplicate button. In the fields provided, give the new profile a Name and, if desired, enter a Description. Click the Active option to make this profile active. Dismiss the Targeter Profiles window, highlight the new profile in the Target Sequence window and click the Edit Controls and Constraints... button. Then, in the Targeter Controls and Constraints window, set up the new profile as desired by editing the appropriate fields.

Advanced Options

This window provides several advanced options for configuring the targeter:

Option	Description
Clear all corrections	Select this option if you want the targeter to clear all corrections made in previous targeting runs each time it performs a new run.
Number of	This integer represents the number of steps into which the

Homotopy Steps	problem should be divided. The targeter will then try up to the maximum number of iterations for each homotopy step.
Scale Controls and Constraints	For each of these options, select among: • By desired value • By one (no scaling) • By specified value (enter value in <u>Targeter Controls and Constraints</u> window) • By tolerance This allows better numerical behavior if the controls or constraints have very different magnitudes.
Use Central Differences	Select this option to use two-sided calculation for derivatives. You may wish to try this option if you find that the targeter is not converging. This will increase the accuracy of the search (though not necessarily that of the ultimate result), but it will roughly double the amount of time consumed by the search.
Line Search	Select this option to perform a line search, and enter values for the lower and upper bounds and for the desired tolerance. Use the Max # of Steps option to specify the maximum number of functions the targeter should call before breaking off the line search and continuing. This will not necessarily help the targeter converge, but it may speed up the process by taking several steps before recalculating the numerical partial derivatives.

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ASTROGATOR COMPONENT BROWSER

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│    ├──☐ MultiBody
│    └──☐ Vehicle Local
├──☐ Vectors
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├──☐ Calculation Objects
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├──☐ Propagators
├──☐ Constraints
├──☐ Stopping Conditions
└──☐ MCS Segments
```
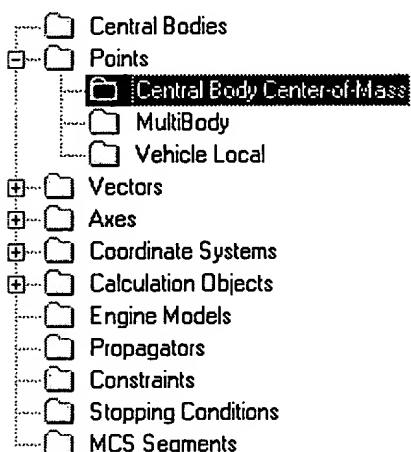
The Astrogator Component Browser is a powerful tool that enables you to redefine components of your space mission analysis and create new ones. To bring up the Component Browser, highlight the Scenario in the STK Browser window and select Astrogator Browser from the Tools menu.

The components are organized into groups listed in a tree structure in the left pane of the component browser. Individual components in a given group or subgroup are displayed in the right pane when you click the corresponding folder or subfolder in the left pane.

Click here for help on:

Central Bodies

Vectors

Coordinate Systems

Engine Models

Constraints

MCS Segments

Points

Axes

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Stopping Conditions

Creating New Components

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Gravity | Parents & Children | Shapes | Attitude | Ephemeris | Atmosphere

Central Bodies

The Component Browser allows you to examine the gravitational, atmospheric, ephemeris and other properties of the nine planets, the Sun, the Moon and other central bodies. In addition, you can create a new central body, such as a comet, asteroid or moon, by duplicating Ceres or another editable central body and redefining one or more of its parameters.

To view and/or edit the properties of a central body, double click it in the right pane of the Component Browser. This brings up the parameters window for the selected central body.

Gravity

The Central Body parameters window allows you to specify the gravitational parameter (μ) and to define and select among gravity models. The value entered in the Gravitational Parameter field is used in point mass force models and propagators and in element set conversions. Enter a value in the scenario distance unit cubed per the scenario time unit squared (e.g. km^3/sec^2).

You can add new gravity models by clicking the ellipsis (...) button to the right of the Gravity Models field, bringing up the Gravity Model Selection window, which is a multi component select window. To edit the features of an existing or newly created model, select it from the list and click the Analytic Details... button. The Gravity Model parameters window appears, offering the following choices:

Field	Description
Gravitational Parameter	Enter the gravitational parameter to be used for purposes of this gravity model (e.g. for inclusion in a full force model) in the scenario distance unit cubed per scenario time unit squared (e.g. km^3/sec^2).
Reference Distance	The distance from the center of mass of the central body to its surface, i.e., approximately the radius of the central body. Typically defaults to the Maximum Radius entered in the Shape frame of the Central Body parameters window.
Zonal - J2	Taking into account first order Earth oblateness effects.
Zonal - J3	Taking into account first order longitudinal variations of the

	Earth's shape.
Zonal - J4	Taking into account first and second order Earth oblateness effects.

Registered gravity models provided by Astrogator for non-editable central bodies include the following:

Model	Central Body
WGS84	Earth
EGM96	Earth
GEMT1	Earth
JGM2	Earth
JGM3	Earth
WGS84 EGM96	Earth
WGS84 old	Earth
GMM1	Mars
Mars50c	Mars
MGNP108U	Venus
GLGM2	Moon

Parents & Children

The Parent field of the Central Body parameters window identifies the parent body of the central body under consideration. To substitute a different parent body, click the ellipsis (...) button to the right of the Parent field and select a new body. For example, if you were using a clone of the asteroid Ceres to model the Saturnian moon Titan, this is where you would assign Saturn the role of parent.

The Children field lists any celestial bodies for which this central body is the principal source of gravitational influence. Thus, for example, if the central body is a planet, this is where any of its moons for which a file exists will be listed.

> ☒ You can, of course, create new moons using the Astrogator capabilities described here.

The Children field cannot be edited; parent-child assignments are handled from the Parent field of the child body. However, you can bring up a list of the central body's children with more detailed information by clicking the ellipsis (...) button to the right of the Children field.

Central Body Shape

For an editable central body, the Shape frame of the Central Body parameters window allows you to select among three different basic shape types:

Shape	Parameters
Sphere	Enter the radius of the spherical central body in the scenario distance unit.
Triaxial Ellipsoid	Enter the semiminor axis, the semimajor axis and the semi-middle axis of the ellipsoidal central body in the scenario distance unit.
Oblate Spheroid	Enter the Minimum and Maximum radii of the oblate spheroidal central body in the scenario distance unit. When you click the OK or Apply button, the Flattening Coefficient appears in a read-only field. This coefficient is calculated by dividing the minor radius by the major radius and subtracting the quotient from 1: $$f = 1 - \frac{r_{min}}{r_{maj}}$$

To add a new shape profile, click the ellipsis (...) button to the right of the Shapes field and make the desired selection in the Shape Selection window that appears. After dismissing the Shape Selection window and returning to the Central Body parameters window, select the new profile in the Shape list and enter its parameters in the appropriate fields.

- For non-editable central bodies, the shape information in the Central Body parameters window and in the Shape Selection window is read-only.

Central Body Attitude

For an editable central body, you can specify the Epoch and the following attitude parameters:

Parameter	Description

Right Ascension	Angle measured in the inertial equatorial plane from the inertial X axis in a right-handed sense about the inertial Z axis to the spin axis -- the angle α in the drawing below. Enter a value in the scenario angle unit.
Declination	The angle from the X-Y plane of the coordinate system to the spin axis vector -- the angle δ in the drawing below. Enter a value in the scenario angle unit. ◻ The North pole lies in the Northern Hemisphere defined by the Mean Ecliptic J2000 plane.
Right Ascension Rate	Rate of change in the right ascension. Enter a value in the scenario angle unit per scenario time unit (e.g. deg/sec).
Declination Rate	Rate of change in the declination. Enter a value in the scenario angle unit per scenario time unit (e.g. deg/sec).
Rotation Offset	Angle from the intertially fixed reference direction to the body-fixed prime meridian (0 deg longitude) at the time of epoch. Enter a value in the scenario angle unit.
Rotation Rate	Rate of the central body's rotation. Enter a value in the scenario angle unit per scenario time unit (e.g. deg/sec). ◻ This should be negative for bodies with retrograde rotation, such as Venus.

$w \equiv Rotation\,Offset$

$\dot{w} \equiv Rotation\,Rate$

$\alpha \equiv Right\,Ascension$

$\delta \equiv Declination$

$Q \equiv Node\,(inertially\,fixed)$
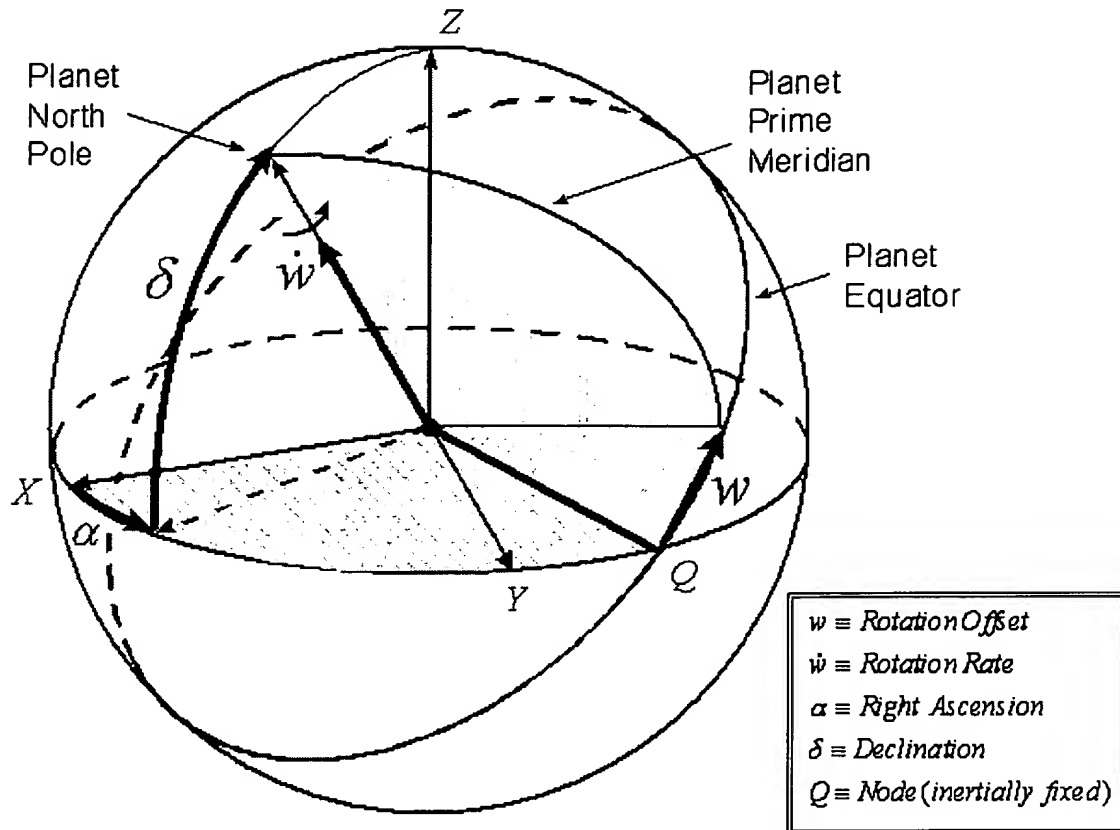
To create an attitude profile, click the ellipsis (...) button to the right of the Attitude field and make the appropriate selections in the Attitude Selection window that appears. You can edit the parameters of an attitude profile by selecting it in the Attitude list, clicking the Analytic Details... button and entering the desired values in the Attitude window that appears.

In addition to editing attitude characteristics, you can use the Attitude window to review the attitude parameters of non-editable central bodies.

Central Body Ephemeris

Astrogator provides the following sources of ephemerides for a central body:

Source	Description
Analytic Orbit	Enter the values and rates of change for the classical orbital elements (see below).
	Enter the path and filename of the external ephemeris (*.e) file in

Ephemeris File	the Ephemeris File field that appears when you select this option, or click the ellipsis (...) button to the right of the Ephemeris File field to browse for a file. ▫ You can use a satellite to model a comet with Astrogator. Generate the satellite's ephemeris, create a data file and then use it as the ephemeris source for the central body.
JPL DE	Ephemerides from the Jet Propulsion Laboratory's JPL DE set are used.
Planetary Ephemeris	Enter the path and filename of the planetary ephemeris (*.pe) file in the Planetary File field that appears when you select this option, or click the ellipsis (...) button to the right of the Planetary File field to browse for a file.

To create one or more ephemeris profiles, click the ellipsis (...) button to the right of the Ephemeris field, and make appropriate selections in the Ephemeris Selection window that appears. Then, to edit the orbital elements of an analytical ephemeris profile, select it in the Ephemeris list and click the Analytic Details... button. An Ephemeris window appears, allowing you to specify an Epoch and the value and rate of change for the classical (Keplerian) orbital elements listed below. These data must be entered with respect to the body's parent, in the parent-inertial coordinate system.

Orbital Element	Definition
Semimajor Axis	One-half the distance along the long axis of the elliptical orbit. Enter a value in the scenario distance unit.
Eccentricity	The ratio of the distance between the two foci of the ellipse and its major axis. Dimensionless.
Inclination	The angle from the Z axis of the inertial coordinate system to the orbit angular velocity vector. Enter a value in the scenario angle unit.
Right Ascension of Ascending Node	The angle from the X axis of the inertial coordinate system to the point where the orbit crosses the X-Y plane in the +Z direction. Enter a value in the scenario angle unit.
Argument of Periapsis	The angle measured in direction of the body's orbital motion, and in the orbit plane, from the ascending node to the periapsis of the orbit. Enter a value in the scenario angle unit.
Mean Longitude	Sum of the Right Ascension of the Ascending Node, the Argument of Periapsis and the Mean Anomaly. Enter a value in

the scenario angle unit.

- Mean Anomaly is the angle measured from periapsis of a hypothetical body moving with a uniform speed that is equal to the Mean Motion, i.e. the uniform rate of a body in a circular orbit of the same period.

In addition to editing orbital elements, you can use the Ephemeris window to review the ephemeris of non-editable central bodies.

Atmospheric Model

Astrogator makes the following Atmospheric Models available for your central body:

Model	Description
Exponential	This model uses the following equation to calculate atmospheric density: $$\rho = \rho_0 e^{\frac{h_0 - h}{H}}$$ where ρ = density at a specified altitude, h = specified altitude, ρ_0 = reference density, h_0 = reference altitude, and H = scale altitude.
Harris-Priester	Takes into account a 10.7 cm solar flux level and diurnal bulge. Uses density tables. Valid range of 0-1000 km.
Jacchia-Roberts	Similar to Jacchia 1971 but uses analytical methods to improve performance.
Jacchia 1960	An outdated atmospheric model provided for making comparisons with other software.
Jacchia 1971	Computes atmospheric density based on the composition of the atmosphere, which depends on altitude as well as seasonal variation. Valid range is 100-2500 km.
US Standard Atmosphere	Standard model with no user-specified parameters.

Points

Astrogator provides a variety of points for use in defining the origin of a coordinate system or the start and end points of a vector. Some of these can be duplicated and used in creating new points. The available types of points include:

Type	Description
Default Origin	This point is provided for duplication and creation of new points.
Earth Center of Mass	For geocentric coordinate systems.
Central Body Center of Mass	A set of points for modeling coordinate systems and vectors with reference to the Sun, Moon, planets and other celestial bodies.
Multi Body	Sun-Earth-Moon L1 and L2 libration points. These can be duplicated as the basis for defining new libration points.
Vehicle Local	Vehicle center of mass.

A brief description of a point is displayed when you highlight it in the Astrogator Component Browser. To view the elements of a point (and edit them, if the point is a copy), double click it in the Component Browser, bringing up its Component Edit window.

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Vectors

The Astrogator Component Browser provides a number of vectors for use in constructing sets of axes, coordinate systems and calculation objects, including several editable ones with which you can create new vectors. The available types include the following:

Type	Description
Cross Product	Cross product of user-selected vectors. Editable.
Displacement	Defined in terms of user-selected start and end points. Editable.
Earth Angular Velocity	Earth angular velocity vector. Not editable.
Unit Vector	Unit vector along user-selected vector. Editable.
User Defined	Defined in terms of user-specified axes and X, Y and Z components. Editable.
Central Body Vectors	Angular velocity vectors for the Sun, Moon, planets and other celestial bodies. Not editable.
Vehicle Local	Nadir, orbit angular momentum, position and velocity. Editable.

A brief description of a vector is displayed when you highlight it in the Astrogator Component Browser. To view the elements of a vector (and edit them, if the vector is a copy), double click it in the Component Browser, bringing up its Component Edit window.
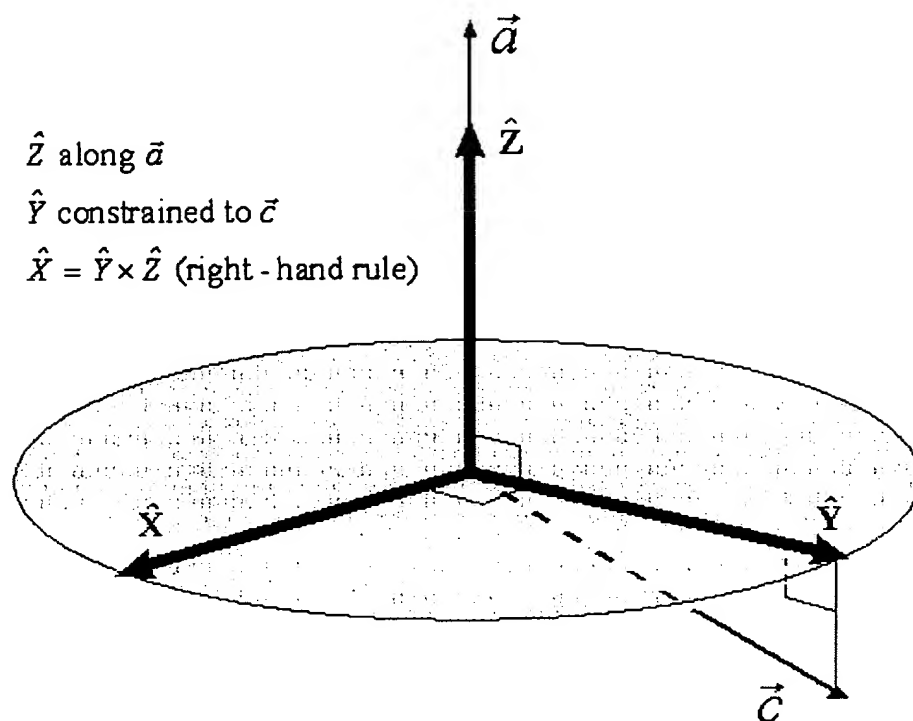
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Axes

The Astrogator Component Browser provides a number of axes for use in constructing coordinate systems, including several editable ones with which you can create new axes. The available types include the following:

Type	Description
2-Vector User Defined	Axes defined by two user-defined vectors. Double click this component in the Component Browser and specify the following: • Axes -- select the pair of axes to be used for alignment and constraint, respectively. • Alignment -- select the vector for alignment and indicate whether the axis is aligned in the + or - direction. • Constraint -- select the vector towards which the axis is to be constrained and indicate whether it is in the + or - direction. Two of the three axes are defined with respect to a pair of vectors (see drawing). The first axis is aligned with one vector, and the second axis is the projection of the other vector onto a plane perpendicular to the first axis. The third axis the cross product of the first two, i.e. derived by the right-hand rule.
Earth Aligned at Epoch	Axes aligned with Earth-fixed at epoch. Editable.
Earth Fixed	Earth-fixed axes. Not editable.
Earth Mean J2000	Mean J2000 axes. The X and Z axes point toward the mean vernal equinox and mean rotation axes of the Earth at January 1, 2000 at 12:00:00.00 UTC. J2000.0 = 2000 January 1.5 = JD 2451545.0 TDT (Terrestrial Dynamical Time). Not editable.
Mean B1950	Mean B1950 axes. Standard epoch defined as the beginning of the Besselian year 1950 (when the longitude of the mean Sun is 280.0 deg measured from the mean equinox) and corresponds to 31 December 1949 22:09:07.2 or JD 2433282.423. Not editable.
Mean Ecliptic	Mean Ecliptic axes. Not editable.
	Mean Equinox True Equator of Date axes. The X and Z axes

Mean Equinox True Equator of Date	point toward the mean vernal equinox and true rotation axis at the current point in time (updated as the spacecraft moves in its orbit). Not editable.
Mean Equinox True Equator of Epoch	Mean Equinox True Equator of Epoch axes. The X and Z axes point toward the mean vernal equinox and true rotation axis at the Epoch date. Editable. Specify a reference epoch.
Mean J2000 (Default Inertial)	Same as Earth Mean J2000 (see above). Not editable.
Mean of Date	Mean of Date axes. The direction of the X axis is defined by the mean vernal equinox and the Z axis is defined by the mean spin axis of the Earth at the time of the state vector. The term 'mean' indicates that precession is accounted for but nutation is not. Not editable.
Mean of Epoch	Mean of Epoch axes. The direction of the X axis is defined by the mean vernal equinox and the Z axis is defined by the mean spin axis of the Earth at a user-specified epoch. The term 'mean' indicates that precession is accounted for but nutation is not. Editable. Specify a reference epoch.
True Ecliptic	True Ecliptic axes. Not editable.
True of Date	True of Date axes. The direction of the X axis is defined by the true vernal equinox and the Z axis is defined by the true spin of the Earth at the time of the state vector. The term 'true' indicates that both precession and nutation have been accounted for. Not editable.
True of Epoch	True of Epoch axes. The direction of the X axis is defined by the true vernal equinox and the Z axis is defined by the true spin of the Earth at a user-specified epoch. The term 'true' indicates that both precession and nutation have been accounted for. Editable. Specify a reference epoch.
Central Body Fixed	Body-fixed axes for the Sun, Moon, planets and other celestial bodies. Data for the Sun, planets and moons are based on the 1994 report of the International Astronomical Union (IAU). Not editable.
Central Body Inertial	Body-inertial axes for the Sun, Moon, planets and other celestial bodies. Not editable.
Multi Body	Body-body rotating (BBR) and Sun-Earth-Moon L1 and L2 libration point axes. Editable.
Vehicle Local	LVLH and VVLH axes, and VNC axes centered on the Earth, the Moon, the Sun, Mars and Venus. Editable.

$\hat{Z}$ along $\vec{a}$

$\hat{Y}$ constrained to $\vec{c}$

$\hat{X} = \hat{Y} \times \hat{Z}$ (right - hand rule)

A brief description of a set of axes is displayed when you highlight it in the Astrogator Component Browser. To view the elements of a set of axes (and edit them, if the set is a copy), double click it in the Component Browser, bringing up its Component Edit window.

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Coordinate Systems

Astrogator makes a number of coordinate systems available for use in constructing other components, including MCS segments such as initial states, maneuvers and propagate segments. Also, you can create new coordinate systems using the Astrogator Component Browser. The types of coordinate systems provided with Astrogator include the following:

Type	Description
Aligned with Fixed at Epoch	Earth-centered inertial coordinate system fixed at the specified epoch. Editable.
Earth Centered Fixed	Earth-centered fixed coordinate system. Not editable.
Earth Centered Mean J2000	Earth-centered Mean J2000 coordinate system. Not editable.
Mean B1950	Earth-centered Mean B1950 coordinate system. Not editable.
Mean Ecliptic of Date	Earth-centered Mean Ecliptic of Date coordinate system. Not editable.
Mean Ecliptic of Epoch	Earth-centered Mean Ecliptic of Epoch coordinate system. Not editable.
Mean Equinox True Equator of Date	Earth-centered Mean Equinox True Equator of Date coordinate system. Not editable.
Mean Equinox True Equator of Epoch	Earth-centered Mean Equinox True Equator of Epoch coordinate system. Editable. Specify the epoch.
Mean of Date	Earth-centered Mean of Date coordinate system. Not editable.
Mean of Epoch	Earth-centered Mean of Epoch coordinate system. Editable. Specify the epoch.
Solar System Barycenter Mean J2000	Solar System Barycenter Mean J2000 coordinate system. Editable.
True Ecliptic of Date	Earth-centered True Ecliptic of Date coordinate system. Not editable.
True Ecliptic of Epoch	Earth-centered True Ecliptic of Epoch coordinate system. Not editable.

True of Date	Earth-centered True of Date coordinate system. Not editable.
True of Epoch	Earth-centered True of Epoch coordinate system. Editable. Specify the epoch.
User Defined	Assembled from user selected origin and axes. Editable.
Central Body Fixed	Body-centered fixed coordinate systems for the Sun, Moon, planets and other celestial bodies. Not editable.
Central Body Inertial	Body-centered inertial coordinate systems for the Sun, Moon, planets and other celestial bodies. Not editable.

A brief description of a coordinate system is displayed when you highlight it in the Astrogator Component Browser. To view the elements of a coordinate system (and edit them, if the coordinate system is a copy), double click it in the Component Browser, bringing up its Component Edit window.

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Calculation Objects

Astrogator makes a number of Calculation Objects available for use in constructing other components, such as stopping conditions, or for use as results, targeter constraints and report and graph elements. Also, you can create new Calculation Objects using the Astrogator Component Browser. The types of Calculation Objects provided with Astrogator include the following:

Type	Description
Epoch	The epoch of a given state in the Mission Control Sequence.
Cartesian Elements	X, Y and Z components of position and velocity vectors.
Geostationary	Longitude drift rate in angle/time, positive toward East.
Geodetic	Latitude, longitude, altitude.
Keplerian Elements	Classical elements specifying an orbit by its size, shape and three-dimensional orientation in space.
Maneuver	ΔV integrated along orbit path.
Math	Absolute value and negative.
Multibody	B-plane elements, delta declination and right ascension.
Other Orbit	Including beta angle, C3 energy, true longitude, etc.
Spherical Elements	Azimuth, right ascension, declination, flight path angle, R magnitude, etc.
Time	Duration from a given epoch.
Vector	Vector components, dot products, angles between vectors, etc.

A brief description of a Calculation Object is displayed when you highlight it in the Astrogator Component Browser. To view the elements of a Calculation Object (and edit them, if the variable is a copy), double click it in the Component Browser, bringing up its Component Edit window.

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Creating New Components

A new component is created in Astrogator by duplicating or 'cloning' an existing component and then editing the clone's properties. Not all components are clonable. To determine whether a given component is clonable, highlight it in the right pane of the Astrogator Component Browser window and observe the Duplicate button at the top of the window. If the button is not disabled (grayed out), the component can be cloned and edited.

To clone a component, highlight it in the Component Browser and click the Duplicate button. In the dialog that appears, rename the new component and, if desired, enter a comment to remind you later why you created it, what it's for, etc.

- You don't have to rename the component. If you don't, Astrogator will assign it a default name such as 'Copy of Earth Point Mass' or 'Copy of Polynomial Thrust and Isp', which, while accurate, won't tell you much about the unique properties of your new component or its role in your mission.

After dismissing the above dialog, you're ready to define the properties that differentiate your new component from the one you copied. Double click the new component in the right pane of the Component Browser and edit away!

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Exercise: Creating Components

In this exercise you will use the Astrogator Component Browser to create a Neptune-centered coordinate system and a Neptune point mass propagator. Then you will use these new components to place a spacecraft in orbit around, you guessed it, Neptune.

Graphics & Map Setup

The following graphics and Map window settings are recommended for this exercise:

Window	Tab	Feature	Recommended Settings
Scenario Graphics	Global Attributes	Show Orbits	ON
		Show Orbit Markers	ON
		other graphics features	OFF
Satellite Graphics	Attributes	Marker Style	X or another graphically simple style, such as Plus, Star, Circle or Square
	Pass	Orbit Lead Type	All
Map Properties	Central Body (Map Toolbar Button)		Neptune
	Details	Items	all geographic features OFF
		Lat/Lon Lines - Show	OFF
		Background - Image	Neptune.bmp
		Type	Orthographic
		Displayed	

		Coordinate Frame	CBI
	Projection	Display Height	100000 km
		Orthographic Grid - Show	ON

Creating a New Coordinate System

To create the new coordinate system, you will:

- Create a pair of vectors
- Define coordinate axes with reference to the vectors
- Use the axes to build a coordinate system with Neptune's center of mass as the origin

USER INPUTS ?

Create Some Vectors

You'll begin by creating three vectors defined in terms of the displacement between the centers of mass of two central bodies. You'll then define a fourth vector as the cross product of two of the displacement vectors.

1. Open the Component Browser and click the Vectors folder.

2. Duplicate the Displacement component and name the copy 'Earth-Sun'.

3. Make another copy of the Displacement component and name it 'Earth-Moon'.

4. Make a third copy of the Displacement component and name it 'Jupiter-Sun'.

5. Double click the Earth-Sun vector, opening its Component Edit window.

6. In the edit window, double-click the End field and select Sun Center of Mass.

7. Following the above procedure, edit the Earth-Moon vector by making Moon Center of Mass the End element.

8. For the Jupiter-Sun vector, make Jupiter Center of Mass the Start element and Sun Center of Mass the End element.

9. Duplicate the Cross Product component and name the copy 'ES-X-EM'.

10. Double click the ES-X-EM vector, opening its Component Edit window.

11. Edit Vector1 by double clicking it and selecting the Earth-Sun vector as the first vector in the cross product.

12. Edit Vector2 by making the Earth-Moon vector the second vector in the cross product.

Create Some Axes

You'll now define a pair of coordinate axes with reference to two of the vectors you have created: the Jupiter-Sun displacement vector and the ES-X-EM cross product vector.

1. Click the Axes folder in the Component Browser.

2. Duplicate the 2-Vector User Defined component and name the copy anything you like.

3. Double click the copy, bringing up the Aligned Coordinate Axes window.

4. In the Axes field, select XZ from the dropdown list. That is, you'll define the X and Z axes and leave the Y axis to be derived by the right hand rule.

5. In the Alignment field, click the ellipsis (...) button and select the Jupiter-Sun vector. Leave the sign at its default value of plus.

6. In the Constraint field, select the ES-X-EM vector. Again, leave the sign at plus.

Build a Coordinate System

To construct a Neptune-centered coordinate system, you'll simply use Neptune's center of mass as the origin and add the two axes you have just defined, letting the third be automatically calculated by the right hand rule as the cross product of the other two.

1. Click the Coordinate Systems folder in the Component Browser.

2. Duplicate the User Defined component and name the copy anything you like.

3. Double click the copy, thereby opening its Component Edit window.

4. In the Axes field, select the coordinate axes you previously created.

5. In the Origin field, select Neptune Center of Mass.

Creating a Neptune Point Mass Propagator

You'll use the coordinate system you created as a frame of reference for defining a

spacecraft orbit around the planet Neptune. It will help to have a propagator that uses Neptune as the central body.

1. Click the Propagators folder in the Component Browser.

2. Duplicate the Earth Point Mass component and name the copy 'Neptune Point Mass'.

3. Double click the copy and, in the Force Models tab, change the Central Body to Neptune.

Designing and Running the MCS

Now it's time to use the components you have created. After setting up a Mission Control Sequence to define and propagate a spacecraft orbit around Neptune, you'll run the MCS and observe dynamic changes in the coordinate system.

Set Up the MCS

A simple MCS, consisting of an Initial State followed by a Propagate segment, will suffice to exercise your newly created coordinate system and propàgator.

1. Highlight the Initial State segment in the MCS and, in the Coordinate System field, select the new coordinate system that you created.

2. Select Keplerian as the Element Type.

3. Enter 1 Jul 1999 as the Orbit Epoch.

▢ It may be necessary to open the Scenario Time Period tab and set the Start and Epoch fields to 1 Jul 1999 as well. Also, open the Animation tab and make sure that the Start Time is set to that date.

   ▢ Set the Semimajor Axis to 30000 km and all the other Keplerian elements to zero.

   ▢ Highlight the Propagate segment and, in the Propagator field, select the Neptune Point Mass propagator that you created.

   ▢ Set the Duration (Trip) value to 7 days (604800 sec).

Run the MCS

Run the MCS. The map window should look something like this when you're finished:
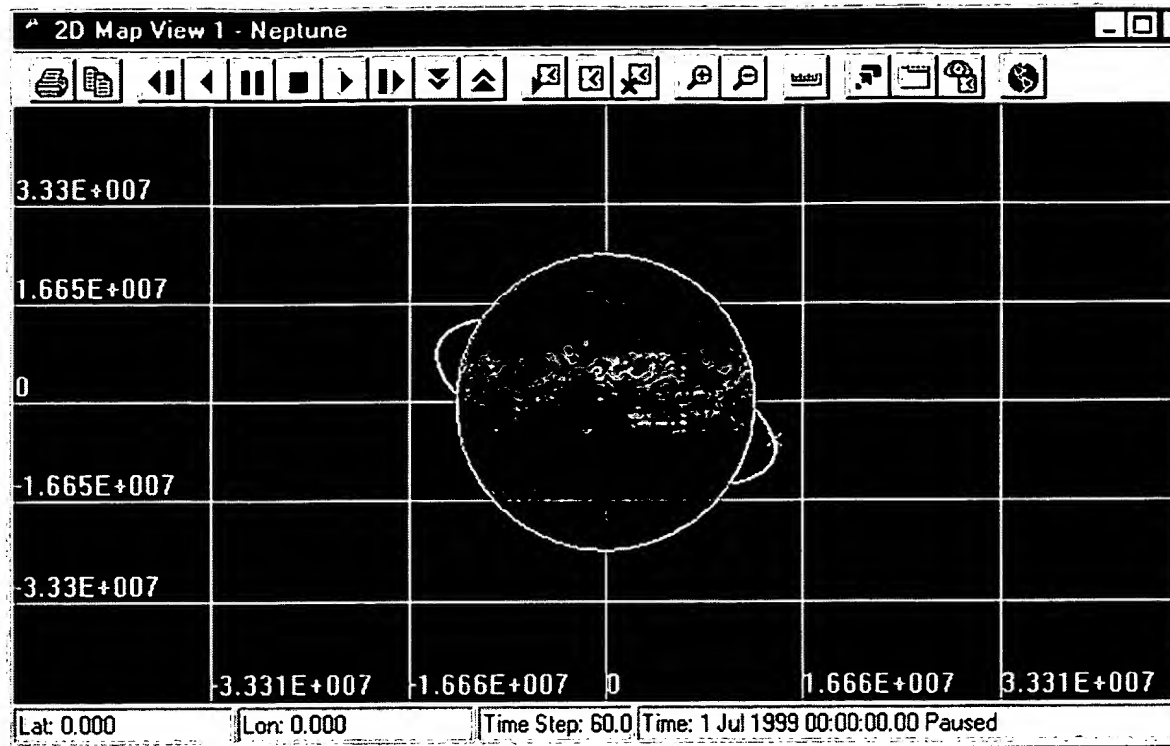
Now recall that the axes used in your coordinate system are defined in terms of vectors that, in turn, are defined (directly or indirectly) with reference to the position of the Earth, the Sun, the Moon and Jupiter. Over time, the relative positions of these celestial bodies change, causing a change of direction in the vectors. Since the axes are defined with reference to the vectors, they, too, must continually be realigned.

To demonstrate this dynamic change in the coordinate system, highlight the Initial State segment and reset the Orbit Epoch to 8 Dec 1999.

- You may need to make a similar change in the Scenario Start and Epoch times, as well as the Animation Start Time.

Run the MCS again. As a result of changes in the relative positions of the Earth, the Sun, the Moon and Jupiter over this period of more than five months, the orientation of the orbit has undergone a considerable change:
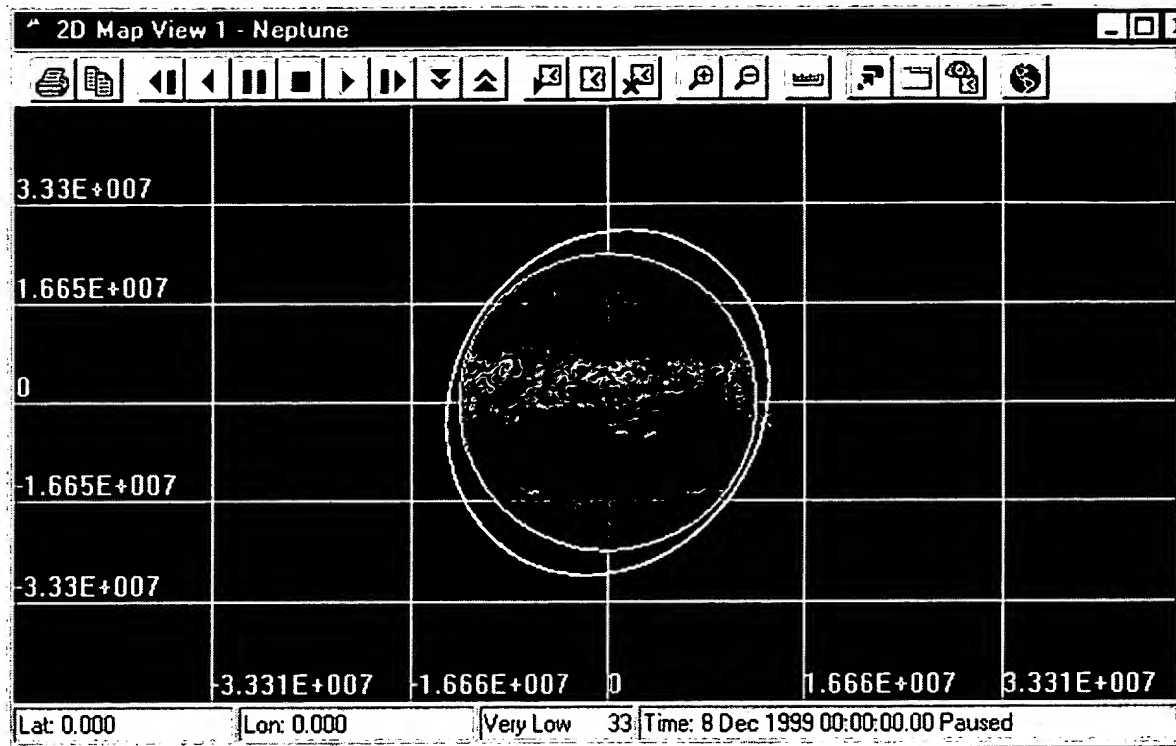
You can also observe the changes in the coordinate axes by using another coordinate system for comparison and observing how the orbital elements change between the two epoch dates. For example, highlight the Initial State segment, bring up its Properties window and change the Coordinate System to Neptune CBI. Then, run a Summary report on the Initial State at each of the two epoch dates and compare such elements as inclination, right ascension of ascending node and argument of periapsis.

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Name	Modified	Size	Ratio	Packed	Path
ab-axes.htm	10/7/1999 5:46 PM	5,966	68%	1,933	gator\
ab-cb.htm	10/7/1999 5:46 PM	14,723	71%	4,270	gator\
ab-clone.htm	10/7/1999 5:46 PM	1,802	54%	832	gator\
ab-cond.htm	10/7/1999 5:46 PM	2,217	58%	928	gator\
ab-coordsys.htm	10/7/1999 5:46 PM	3,788	73%	1,017	gator\
ab-engine.htm	10/7/1999 5:46 PM	4,102	64%	1,465	gator\
ab-intro.htm	10/7/1999 5:46 PM	2,310	59%	939	gator\
ab-mcsseg.htm	10/7/1999 5:46 PM	1,641	59%	674	gator\
ab-points.htm	10/7/1999 5:46 PM	1,935	57%	839	gator\
ab-prop.htm	10/7/1999 5:46 PM	12,325	71%	3,565	gator\
ab-state.htm	10/7/1999 5:46 PM	2,790	59%	1,156	gator\
ab-stopcond.htm	10/7/1999 5:46 PM	3,230	66%	1,107	gator\
ab-vectors.htm	10/7/1999 5:46 PM	2,122	58%	896	gator\
astrogator.gif	10/7/1999 5:46 PM	27,190	0%	27,070	gator\
astrogator.htm	10/7/1999 5:46 PM	1,420	59%	584	gator\
banner.htm	10/7/1999 5:46 PM	1,802	62%	686	gator\
blubvblt.gif	10/7/1999 5:46 PM	57	0%	57	gator\
blubvidx.gif	10/7/1999 5:46 PM	460	8%	422	gator\
blubvpnx.gif	10/7/1999 5:46 PM	477	8%	440	gator\
blubvppv.gif	10/7/1999 5:46 PM	480	8%	443	gator\
blubvspm.gif	10/7/1999 5:46 PM	137	0%	137	gator\
blubvtoc.gif	10/7/1999 5:46 PM	426	9%	389	gator\
blubvtop.gif	10/7/1999 5:46 PM	442	9%	403	gator\
btn-clear.gif	10/7/1999 5:46 PM	934	80%	190	gator\
btn-copy.gif	10/7/1999 5:46 PM	942	79%	202	gator\
btn-cut.gif	10/7/1999 5:46 PM	916	81%	170	gator\
btn-delete.gif	10/7/1999 5:46 PM	926	80%	185	gator\
btn-go.gif	10/7/1999 5:46 PM	969	76%	233	gator\
btn-insert.gif	10/7/1999 5:46 PM	929	80%	187	gator\
btn-mcbrowser.gif	10/7/1999 5:46 PM	968	76%	229	gator\
btn-mcsopts.gif	10/7/1999 5:46 PM	944	78%	203	gator\
btn-paste.gif	10/7/1999 5:46 PM	952	77%	217	gator\
btn-props.gif	10/7/1999 5:46 PM	963	77%	226	gator\
btn-summary.gif	10/7/1999 5:46 PM	937	79%	198	gator\
bullet.gif	10/7/1999 5:46 PM	287	32%	196	gator\
compedit.gif	10/7/1999 5:46 PM	8,330	8%	7,625	gator\
components.gif	10/7/1999 5:46 PM	1,687	0%	1,687	gator\
cranbspm.gif	10/7/1999 5:46 PM	160	24%	122	gator\
DLS.sc	10/7/1999 5:46 PM	15,555	75%	3,844	gator\DLS\
Moon.pl	10/7/1999 5:46 PM	1,326	66%	455	gator\DLS\
Sat1.sa	10/7/1999 5:46 PM	317,225	82%	58,101	gator\DLS\
dwgaxes.gif	10/7/1999 5:46 PM	5,142	14%	4,427	gator\
dwgbplane.gif	10/7/1999 5:46 PM	6,200	11%	5,513	gator\
dwgbplane2.gif	10/7/1999 5:46 PM	2,994	23%	2,304	gator\
dwgbplane3.gif	10/7/1999 5:46 PM	3,828	18%	3,126	gator\
dwgrlp.gif	10/7/1999 5:46 PM	3,581	20%	2,878	gator\
dwgrlp2.gif	10/7/1999 5:46 PM	4,350	16%	3,646	gator\
dwgtargvec.gif	10/7/1999 5:46 PM	3,768	19%	3,065	gator\
eq-bplane.htm	10/7/1999 5:46 PM	7,420	70%	2,224	gator\
eq-coordsys.htm	10/7/1999 5:46 PM	2,396	66%	813	gator\
eq-diffcorr.htm	10/7/1999 5:46 PM	5,332	62%	2,003	gator\
eq-dvint.htm	10/7/1999 5:46 PM	1,315	51%	641	gator\
eq-models.htm	10/7/1999 5:46 PM	3,667	66%	1,245	gator\

Name	Modified	Size	Ratio	Packed	Path
eq-rlp.htm	10/7/1999 5:46 PM	7,892	70%	2,371	gator\
eq-solar.htm	10/7/1999 5:46 PM	1,633	55%	741	gator\
eq-technotes.htm	10/7/1999 5:46 PM	1,361	53%	641	gator\
eqatmosdens.gif	10/7/1999 5:46 PM	1,005	75%	255	gator\
eqbplane-1.gif	10/7/1999 5:46 PM	1,633	93%	112	gator\
eqbplane-10.gif	10/7/1999 5:46 PM	1,862	81%	354	gator\
eqbplane-11.gif	10/7/1999 5:46 PM	1,888	80%	384	gator\
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eqbplane-13.gif	10/7/1999 5:46 PM	1,619	94%	97	gator\
eqbplane-14.gif	10/7/1999 5:46 PM	1,851	81%	344	gator\
eqbplane-15.gif	10/7/1999 5:46 PM	1,913	79%	409	gator\
eqbplane-16.gif	10/7/1999 5:46 PM	1,646	92%	125	gator\
eqbplane-17.gif	10/7/1999 5:46 PM	1,898	79%	391	gator\
eqbplane-18.gif	10/7/1999 5:46 PM	1,729	88%	213	gator\
eqbplane-19.gif	10/7/1999 5:46 PM	1,633	93%	112	gator\
eqbplane-2.gif	10/7/1999 5:46 PM	1,632	93%	109	gator\
eqbplane-20.gif	10/7/1999 5:46 PM	1,724	88%	209	gator\
eqbplane-21.gif	10/7/1999 5:46 PM	1,814	83%	304	gator\
eqbplane-22.gif	10/7/1999 5:46 PM	2,060	73%	563	gator\
eqbplane-23.gif	10/7/1999 5:46 PM	2,141	70%	648	gator\
eqbplane-3.gif	10/7/1999 5:46 PM	1,630	93%	108	gator\
eqbplane-4.gif	10/7/1999 5:46 PM	1,634	93%	113	gator\
eqbplane-5.gif	10/7/1999 5:46 PM	1,622	94%	100	gator\
eqbplane-6.gif	10/7/1999 5:46 PM	1,618	94%	96	gator\
eqbplane-7.gif	10/7/1999 5:46 PM	1,620	94%	97	gator\
eqbplane-8.gif	10/7/1999 5:46 PM	1,819	83%	309	gator\
eqbplane-9.gif	10/7/1999 5:46 PM	2,033	74%	537	gator\
eqcoord-1.gif	10/7/1999 5:46 PM	1,634	93%	113	gator\
eqcoord-2.gif	10/7/1999 5:46 PM	1,726	88%	211	gator\
eqcoord-3.gif	10/7/1999 5:46 PM	1,709	89%	192	gator\
eqcoord-4.gif	10/7/1999 5:46 PM	1,654	92%	134	gator\
eqcoord-5.gif	10/7/1999 5:46 PM	1,778	85%	266	gator\
eqcoord-6.gif	10/7/1999 5:46 PM	1,708	89%	191	gator\
eqcoord-7.gif	10/7/1999 5:46 PM	1,709	89%	193	gator\
eqcoord-8.gif	10/7/1999 5:46 PM	1,710	89%	194	gator\
eqdiffcorr-1.gif	10/7/1999 5:46 PM	2,533	58%	1,068	gator\
eqdiffcorr-2.gif	10/7/1999 5:46 PM	2,044	73%	549	gator\
eqdiffcorr-3.gif	10/7/1999 5:46 PM	2,475	59%	1,006	gator\
eqdiffcorr-5.gif	10/7/1999 5:46 PM	2,144	70%	652	gator\
eqdiffcorr-6.gif	10/7/1999 5:46 PM	2,077	72%	583	gator\
eqdiffcorr-7.gif	10/7/1999 5:46 PM	3,502	42%	2,035	gator\
eqdiffcorr-8.gif	10/7/1999 5:46 PM	1,749	87%	236	gator\
eqdv1fx.gif	10/7/1999 5:46 PM	1,777	85%	265	gator\
eqdv2fx.gif	10/7/1999 5:46 PM	2,042	73%	544	gator\
eqdvint-1.gif	10/7/1999 5:46 PM	1,819	83%	309	gator\
eqdvint-2.gif	10/7/1999 5:46 PM	1,798	84%	286	gator\
eqdvmag.gif	10/7/1999 5:46 PM	2,206	67%	721	gator\
eqeccanom.gif	10/7/1999 5:46 PM	1,412	51%	688	gator\
eqeccentric.gif	10/7/1999 5:46 PM	1,744	87%	230	gator\
eqenergy.gif	10/7/1999 5:46 PM	1,777	85%	265	gator\
eqenergyfx.gif	10/7/1999 5:46 PM	1,745	87%	231	gator\
eqengine-1.gif	10/7/1999 5:46 PM	1,907	79%	404	gator\
eqengine-2.gif	10/7/1999 5:46 PM	1,789	84%	278	gator\

Name	Modified	Size	Ratio	Packed	Path
eqengine-3.gif	10/7/1999 5:46 PM	1,868	81%	361	gator\
eqengine-4.gif	10/7/1999 5:46 PM	1,630	93%	109	gator\
eqengine-5.gif	10/7/1999 5:46 PM	1,737	87%	222	gator\
eqengine-6.gif	10/7/1999 5:46 PM	1,969	76%	466	gator\
eqengine-7.gif	10/7/1999 5:46 PM	1,830	82%	321	gator\
eqengine-8.gif	10/7/1999 5:46 PM	1,980	76%	480	gator\
eqhohdv1.gif	10/7/1999 5:46 PM	1,777	85%	265	gator\
eqhohdv2.gif	10/7/1999 5:46 PM	1,777	85%	264	gator\
eqlawcos.gif	10/7/1999 5:46 PM	2,014	74%	516	gator\
eqmeananom.gif	10/7/1999 5:46 PM	2,005	75%	506	gator\
eqrlp-1.gif	10/7/1999 5:46 PM	2,200	68%	713	gator\
eqrlp-10.gif	10/7/1999 5:46 PM	1,633	93%	112	gator\
eqrlp-11.gif	10/7/1999 5:46 PM	1,634	93%	113	gator\
eqrlp-12.gif	10/7/1999 5:46 PM	1,782	85%	270	gator\
eqrlp-13.gif	10/7/1999 5:46 PM	2,070	72%	574	gator\
eqrlp-14.gif	10/7/1999 5:46 PM	1,874	80%	368	gator\
eqrlp-15.gif	10/7/1999 5:46 PM	1,650	92%	130	gator\
eqrlp-16.gif	10/7/1999 5:46 PM	2,050	73%	553	gator\
eqrlp-17.gif	10/7/1999 5:46 PM	3,223	45%	1,757	gator\
eqrlp-18.gif	10/7/1999 5:46 PM	2,406	61%	932	gator\
eqrlp-19.gif	10/7/1999 5:46 PM	1,727	88%	213	gator\
eqrlp-2.gif	10/7/1999 5:46 PM	2,195	68%	708	gator\
eqrlp-20.gif	10/7/1999 5:46 PM	2,047	73%	550	gator\
eqrlp-21.gif	10/7/1999 5:46 PM	2,575	57%	1,107	gator\
eqrlp-22.gif	10/7/1999 5:46 PM	1,668	91%	148	gator\
eqrlp-23.gif	10/7/1999 5:46 PM	2,367	62%	888	gator\
eqrlp-24.gif	10/7/1999 5:46 PM	1,639	93%	118	gator\
eqrlp-25.gif	10/7/1999 5:46 PM	1,646	92%	125	gator\
eqrlp-26.gif	10/7/1999 5:46 PM	1,621	94%	99	gator\
eqrlp-27.gif	10/7/1999 5:46 PM	1,627	93%	106	gator\
eqrlp-28.gif	10/7/1999 5:46 PM	1,618	94%	96	gator\
eqrlp-29.gif	10/7/1999 5:46 PM	1,628	93%	107	gator\
eqrlp-3.gif	10/7/1999 5:46 PM	2,347	63%	870	gator\
eqrlp-30.gif	10/7/1999 5:46 PM	1,637	93%	116	gator\
eqrlp-31.gif	10/7/1999 5:46 PM	1,625	94%	102	gator\
eqrlp-32.gif	10/7/1999 5:46 PM	2,266	65%	783	gator\
eqrlp-33.gif	10/7/1999 5:46 PM	2,285	65%	804	gator\
eqrlp-34.gif	10/7/1999 5:46 PM	3,397	43%	1,930	gator\
eqrlp-35.gif	10/7/1999 5:46 PM	1,729	88%	213	gator\
eqrlp-36.gif	10/7/1999 5:46 PM	1,988	75%	488	gator\
eqrlp-37.gif	10/7/1999 5:46 PM	1,830	82%	321	gator\
eqrlp-4.gif	10/7/1999 5:46 PM	2,143	70%	651	gator\
eqrlp-5.gif	10/7/1999 5:46 PM	1,784	85%	272	gator\
eqrlp-6.gif	10/7/1999 5:46 PM	1,809	83%	299	gator\
eqrlp-7.gif	10/7/1999 5:46 PM	1,624	94%	103	gator\
eqrlp-8.gif	10/7/1999 5:46 PM	1,630	93%	109	gator\
eqrlp-9.gif	10/7/1999 5:46 PM	1,615	94%	93	gator\
eqsolar-1.gif	10/7/1999 5:46 PM	2,108	71%	613	gator\
eqsolar-2.gif	10/7/1999 5:46 PM	1,628	93%	107	gator\
eqsolar-3.gif	10/7/1999 5:46 PM	1,634	93%	112	gator\
eqtof.gif	10/7/1999 5:46 PM	1,879	80%	373	gator\
eqtrueanom.gif	10/7/1999 5:46 PM	2,059	73%	560	gator\
equations.gif	10/7/1999 5:46 PM	1,548	0%	1,548	gator\

Name	Modified	Size	Ratio	Packed	Path
eqvecangle.gif	10/7/1999 5:46 PM	2,038	73%	542	gator\
eqvelocity.gif	10/7/1999 5:46 PM	1,942	77%	441	gator\
eqvsubi.gif	10/7/1999 5:46 PM	1,805	84%	295	gator\
eqvsubo.gif	10/7/1999 5:46 PM	1,812	83%	302	gator\
eqvsubta.gif	10/7/1999 5:46 PM	1,651	92%	131	gator\
eqvsubtp.gif	10/7/1999 5:46 PM	1,655	92%	135	gator\
eqvtofx.gif	10/7/1999 5:46 PM	1,987	75%	487	gator\
eqvtpfx.gif	10/7/1999 5:46 PM	1,989	75%	489	gator\
fadetowhite.gif	10/7/1999 5:46 PM	1,941	0%	1,941	gator\
Flatcoef.gif	10/7/1999 5:46 PM	277	3%	269	gator\
frame.htm	10/7/1999 5:46 PM	846	61%	332	gator\
gkalpha.gif	10/7/1999 5:46 PM	1,621	94%	99	gator\
gkdelta-uc.gif	10/7/1999 5:46 PM	1,625	94%	104	gator\
gkdelta.gif	10/7/1999 5:46 PM	1,623	94%	102	gator\
gkgamma.gif	10/7/1999 5:46 PM	1,624	94%	102	gator\
gkmu.gif	10/7/1999 5:46 PM	1,627	93%	106	gator\
gknu.gif	10/7/1999 5:46 PM	1,615	94%	93	gator\
gkphi.gif	10/7/1999 5:46 PM	1,631	93%	109	gator\
gkrho.gif	10/7/1999 5:46 PM	1,628	93%	106	gator\
gktheta.gif	10/7/1999 5:46 PM	1,624	94%	102	gator\
helpmap.gif	10/7/1999 5:46 PM	1,301	49%	667	gator\
HelpSearch.htm	10/7/1999 5:46 PM	548	37%	345	gator\
HelpSearch.jar	10/7/1999 5:46 PM	11,317	2%	11,096	gator\
kepler.gif	10/7/1999 5:46 PM	5,747	15%	4,862	gator\
mc-browser.htm	10/7/1999 5:46 PM	1,820	56%	803	gator\
mc-edit.htm	10/7/1999 5:46 PM	5,820	67%	1,923	gator\
mc-launch.htm	10/7/1999 5:46 PM	5,478	71%	1,614	gator\
mc-maneuvers.htm	10/7/1999 5:46 PM	8,068	68%	2,610	gator\
mc-options.htm	10/7/1999 5:46 PM	3,757	62%	1,411	gator\
mc-other.htm	10/7/1999 5:46 PM	2,311	57%	999	gator\
mc-prop.htm	10/7/1999 5:46 PM	5,408	65%	1,891	gator\
mc-segments.htm	10/7/1999 5:46 PM	1,606	51%	791	gator\
mc-states.htm	10/7/1999 5:46 PM	14,434	77%	3,349	gator\
mc-targeting.htm	10/7/1999 5:46 PM	13,571	71%	3,943	gator\
mcs.gif	10/7/1999 5:46 PM	1,332	25%	1,005	gator\
mxrhosubo.gif	10/7/1999 5:46 PM	110	2%	108	gator\
planes-1.gif	10/7/1999 5:46 PM	2,141	70%	649	gator\
planes-2.gif	10/7/1999 5:46 PM	1,952	77%	452	gator\
planes-3.gif	10/7/1999 5:46 PM	1,739	87%	225	gator\
planes-4.gif	10/7/1999 5:46 PM	1,750	86%	237	gator\
planes-5.gif	10/7/1999 5:46 PM	4,196	35%	2,725	gator\
planes-6.gif	10/7/1999 5:46 PM	1,883	80%	379	gator\
planes-7.gif	10/7/1999 5:46 PM	2,049	73%	550	gator\
planes-8.gif	10/7/1999 5:46 PM	2,675	55%	1,212	gator\
planes-9.gif	10/7/1999 5:46 PM	2,119	70%	627	gator\
popup.gif	10/7/1999 5:46 PM	4,507	16%	3,807	gator\
pxcomponents.gif	10/7/1999 5:46 PM	3,652	19%	2,955	gator\
pxfastrans.gif	10/7/1999 5:46 PM	5,647	26%	4,179	gator\
pxfieldedit.gif	10/7/1999 5:46 PM	3,212	22%	2,518	gator\
pxhohcombo.gif	10/7/1999 5:46 PM	3,440	20%	2,762	gator\
pxhohmann.gif	10/7/1999 5:46 PM	5,557	26%	4,091	gator\
pxhohmannex.gif	10/7/1999 5:46 PM	2,281	30%	1,602	gator\
pxhohplane.gif	10/7/1999 5:46 PM	4,057	17%	3,379	gator\

Name	Modified	Size	Ratio	Packed	Path
pxmap1st.gif	10/7/1999 5:46 PM	2,656	26%	1,971	gator\
pxmap2nd.gif	10/7/1999 5:46 PM	2,736	25%	2,051	gator\
pxmaphohcombo.gif	10/7/1999 5:46 PM	10,071	6%	9,499	gator\
pxmaphohplane.gif	10/7/1999 5:46 PM	11,833	5%	11,294	gator\
pxmarsorbit.gif	10/7/1999 5:46 PM	12,442	1%	12,371	gator\
pxmarsview.gif	10/7/1999 5:46 PM	12,524	1%	12,461	gator\
pxmarsvo.gif	10/7/1999 5:46 PM	66,659	1%	66,222	gator\
pxmcs.gif	10/7/1999 5:46 PM	3,192	21%	2,510	gator\
pxmultics.gif	10/7/1999 5:46 PM	14,741	5%	14,050	gator\
pxneptuneafter.gif	10/7/1999 5:46 PM	21,311	2%	20,910	gator\
pxneptunebefore.gif	10/7/1999 5:46 PM	20,987	2%	20,553	gator\
pxnestedseg.gif	10/7/1999 5:46 PM	2,930	23%	2,254	gator\
pxreturn.gif	10/7/1999 5:46 PM	1,808	38%	1,129	gator\
pxsinglecs.gif	10/7/1999 5:46 PM	8,835	8%	8,148	gator\
pxsunview.gif	10/7/1999 5:46 PM	11,300	6%	10,667	gator\
pxtgtcheck.gif	10/7/1999 5:46 PM	1,390	51%	684	gator\
pxvvlh.gif	10/7/1999 5:46 PM	5,096	11%	4,526	gator\
ra_dec.gif	10/7/1999 5:46 PM	12,082	12%	10,611	gator\
search.gif	10/7/1999 5:46 PM	1,450	0%	1,450	gator\
squarebrowser.gif	10/7/1999 5:46 PM	2,875	24%	2,181	gator\
squareequations.gif	10/7/1999 5:46 PM	2,369	29%	1,675	gator\
squareexercise.gif	10/7/1999 5:46 PM	2,951	21%	2,341	gator\
squaremcs.gif	10/7/1999 5:46 PM	3,521	19%	2,841	gator\
stkstyle.css	10/7/1999 5:46 PM	2,580	69%	812	gator\
TableOfContents.htm	10/7/1999 5:46 PM	4,387	76%	1,059	gator\
tq-fastrans.htm	10/7/1999 5:46 PM	6,819	66%	2,328	gator\
tq-hohmann.htm	10/7/1999 5:46 PM	3,458	63%	1,293	gator\
tq-planes.htm	10/7/1999 5:46 PM	4,209	65%	1,493	gator\
tx-components.htm	10/7/1999 5:46 PM	10,048	68%	3,231	gator\
tx-dls.htm	10/7/1999 5:46 PM	11,180	63%	4,117	gator\
tx-fastrans.htm	10/7/1999 5:46 PM	12,368	69%	3,881	gator\
tx-hohmann.htm	10/7/1999 5:46 PM	8,799	66%	2,979	gator\
tx-intro.htm	10/7/1999 5:46 PM	1,171	59%	476	gator\
tx-marsprobe.htm	10/7/1999 5:46 PM	12,023	66%	4,061	gator\
tx-marsvo.htm	10/7/1999 5:46 PM	4,391	58%	1,849	gator\
tx-planes.htm	10/7/1999 5:46 PM	18,759	74%	4,967	gator\
tx-targeting.htm	10/7/1999 5:46 PM	10,097	69%	3,133	gator\
ui-compedit.htm	10/7/1999 5:46 PM	1,423	52%	687	gator\
ui-multics.htm	10/7/1999 5:46 PM	2,200	58%	931	gator\
ui-singlecs.htm	10/7/1999 5:46 PM	1,335	52%	637	gator\
vecvsubo.gif	10/7/1999 5:46 PM	1,650	92%	130	gator\
vecvsubt.gif	10/7/1999 5:46 PM	1,649	92%	129	gator\
254 file(s)		**1,224,123**	**56%**	**538,774**	